

PRELIMINARY EXPERIMENTS WITH ESCARPMENT DEGRADATION IN FROZEN SEDIMENT: MORPHOLOGY, PROCESS, AND IMPLICATIONS FOR LANDFORMS ON MARS R. C. Kochel, Department of Geology, Bucknell University and M. Carr, Department of Geological Sciences, Old Dominion University

Interaction of ground-ice or permafrost has been advocated to explain a range of landform assemblages on Mars (Sharp 1973; Carr and Schaber 1977; Squyres 1984; Lucchitta 1987). Our understanding of the geomorphic signature left by ice-degradational processes along escarpments is modest, even for terrestrial settings.

A series of simple preliminary experiments were designed to begin developing a simplistic morphometric model for the evolution of degradational landforms along escarpments in frozen terrain. Sand and silt-sized sediments were frozen in a steel test chamber measuring 1m x 0.6m x 0.5m. Following a 48 to 72-hour freeze-up period, the front panel of the box was removed to expose a frozen escarpment for observation. Thawing was done rapidly by using heating elements mounted under the base of the box to simulate the effects of an intrusion beneath the frozen regolith. Although not performed under controlled Martian atmospheric conditions, the five initial experiments produced a replicable scenario of degradational landform evolution whose features could be compared to similar morphologies along major escarpments on Mars.

Four distinctive morphogenetic stages were common to the initial experiments: 1) water-dominated; 2) slumping; 3) vapor release; and 4) surface collapse. Within 30-40 minutes of basal heating, active sapping was observed along the lower few cm of the escarpment. Sapping initially occurred across the entire width of the escarpment, but soon became focused at several locations, resulting in the formation of sizable alcoves. Broad, low-gradient alluvial fans rapidly formed downslope from the alcoves from these discharges. During the latter part of this first stage, one or more fumaroles appeared within the sapping horizons. These fumaroles vented steam with significant lateral pressure and were also characterized by episodic catastrophic release of mud, sand, and water. Sand was ejected 25-30 cm in front of the escarpment by some of the more violent bursts. Viscous mudflows released from these vents deposited large lobate deposits on the proximal and mid-fan reaches of the alluvial fans forming along the base of the escarpment.

Episodic mudflows continued into the second stage of development which was marked by the onset of large-scale mass movements, primarily in the form of slumps and occasional slab failures. Initial slumping was usually preceded by bulging of the escarpment walls from the buildup of vapor pressure and was accompanied by significant venting of steam and release of water. With time, the size of the slump blocks increased as thawing proceeded toward the surface in the latter part of stage 2. The blocky colluvium from stage 2 was emplaced on top of the mudflow fans from stage 1, primarily in their proximal reaches. After several hours dominated by slumping, most of the ground-ice had melted and was released. A notable decline in the rate of slumping accompanied by the cessation of water release characterized stage 3 of the scarp evolution. This stage was characterized by non-point source steam emissions as the remaining water was vaporized and thaw proceeded to the surface.

Once the surface layers thawed, subsidence features began forming, signaling the final stage in landform evolution in these experiments. In some cases, surface collapse was observed in stages 2 and 3, but the rate of surface collapse generally increased toward the end of the 12-16 hour runs. Collapse features included irregular depressions, arcuate to linear grabens associated with slumping, and semi-circular thermokarst sinks directly above the heating elements. Collapsed reaches could generally be traced in the subsurface to pipes that exited along the escarpment face, usually in the vicinity of the major alcoves. Subsidence occurred into voids left by the evacuation of both ice and sediments discharged during the early mudflow phases of

degradation once the unconsolidated sediments lost shear strength upon degradation of their ice cement in the late stages of the evolution.

Figure 1 shows a schematic of the scarp degradational features developed. The major landforms are characterized by highly fractured chaotic slump blocks underlain by mudflow fans formed in earlier stages. The plateau surface produced was uneven and punctuated by thermokarst depressions and tension fractures. Although these observations are from a preliminary and crude experimental design, they may have significant implications for interpreting landform evolution along escarpments on Mars. These experiments suggest that rapid degradation of frozen sediments in escarpments from basal heat sources can result in the explosive release (geysering) of volatiles and sediment. The overall character of degradational landforms produced has many morphologic similarities to features observed along Martian escarpments. For example: 1) the slumps and mudflow fans resemble similar landforms observed within Ophir Chasma and Candor Chasma of Valles Marineris; 2) the arcuate fractures along the escarpment rim and the polygonal pattern of some of the slump blocks resembles Martian forms seen in Noctis Labyrinthus and along some areas of the cratered terrain boundary; and 3) surface collapse features resemble pseudocraters and other possible collapse features in the plateaus proximal to Valles Marineris.

The observations of the genesis escarpments with proximal slump blocks and distal mudflow fans bear a particular similarity to features described by Lucchitta (1987) in Ophir and Candor Chasma on Mars. Lucchitta (1987) suggested that these landforms evolved with slumping first, followed by the mobilization of debris from the toe area. Our experiments produced a similar landform assemblage, however, the sequence of formative events was the formation of the mudflow fans first, followed by slumping in later stages.

Future experiments anticipated will involve the quantification of degradation processes and fluid release, conducting experiments with a variety of stratigraphic and structural arrangements, experiments with different modes of thaw, and experiments run using lower atmospheric pressures.

References Cited:

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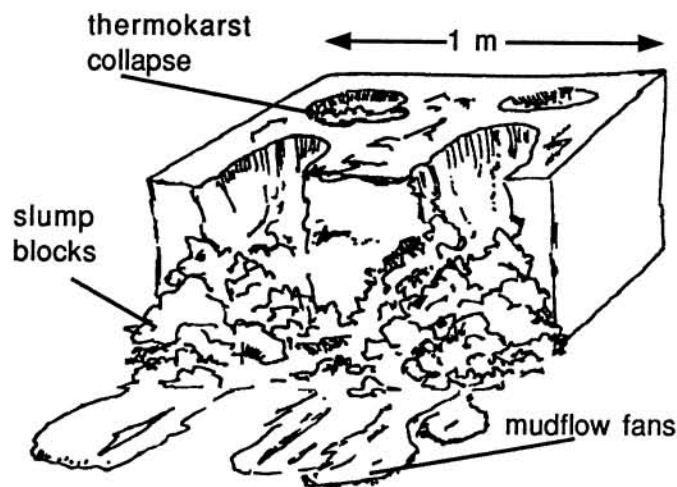


Figure 1. Schematic showing landform assemblage along experimental escarpment following the degradation of frozen sediments due to basal heating.